

Predator Impacts on Salvage Rates of Juvenile Chinook Salmon and Delta Smelt

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Summary

The Sacramento-San Joaquin River Delta delivers approximately 8.0 million acre feet of water annually to Central and Southern California for agriculture, municipal, and industrial needs. The water is diverted and transported by two primary pumping facilities: C.W. “Bill” Jones Pumping Plant (Tracy Pumping Plant) and Harvey O. Banks Delta Pumping Plant. Both sites are equipped with fish salvaging facilities upstream of the pumping plants to reduce the number of fish entrained to the pumps and into the water deliveries. Both the federal Tracy Fish Collection Facility (TFCF) and the state Skinner Delta Fish Protective Facility use a behavioral type louver-bypass system to guide fish out of the canal and into collection tanks where the salvaged fish are held and then transported and released back into the Delta. Efficiency of the louvering systems to guide fish through each facility is potentially negatively influenced by non-native predators residing near as well as within the facilities. These non-native predators directly influence salvage rates by consuming smaller entrained native species.

Non-native predatory fish, *i.e.*, striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. delomieu*), spotted bass (*M. punctulatus*), white bass (*M. chrysops*), channel catfish (*Ictalurus punctatus*), blue catfish (*I. furcatus*), white catfish (*Ameiurus catus*), black bullhead (*A. melas*), brown bullhead (*A. nebulosus*), bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), redear sunfish (*L. microlophus*), warmouth (*L. gulosus*), green sunfish (*L. cyanellus*), black crappie (*Pomoxis nigromaculatus*), white crappie (*P. annularis*), inhabit the Sacramento-San

Joaquin River Delta area in and near the TFCF (Reyes *et al.* 2007). These non-native fish, particularly striped bass, are often found in relatively high numbers within the TFCF as well as upstream and downstream of the facility. Striped bass are highly piscivorous and prey on native fish, particularly when they are migrating and subsequently entrained into the TFCF.

Endangered and threatened species such as juvenile Chinook salmon (*Oncorhynchus tshawytscha*) juvenile steelhead (*O. mykiss*), and adult and juvenile delta smelt (*Hypomesus transpacificus*) are often salvaged in high numbers during the winter and spring months. During these periods, these threatened and endangered species become the primary staple for non-native predator fish, particularly for adult and sub-adult striped bass. Juvenile striped bass may also negatively impact TFCF salvage rates. Delta smelt were listed as a threatened species on March 5, 1993 (58 FR12854). Sacramento winter-run Chinook salmon were listed as a threatened species under an emergency rule August 4, 1989 (54 FR 10260), final rule for threatened status on November 5, 1990 (55 FR 46515), and re-classified as endangered on January 4, 1994 (59 FR 440). Central Valley spring-run Chinook salmon were listed as a threatened species on September 16, 1999 (64 FR 50394). The final rule for listing Central Valley steelhead as a threatened species occurred on March 19, 1998 (63 FR 13347).

While the ratio of adult, sub-adult, and juvenile striped bass may vary seasonally, the predatory species are omnipresent residing upstream, downstream, and within the TFCF primary channel (Bark *et al. in progress*). The louver panels of the TFCF primary channel are individually lifted and cleaned one to several times per day allowing striped bass to move in and out of the primary channel thus, the primary channel is not a closed system. Cleaning the louvers is necessary to ensure their effectiveness to guide fish into the collection system and to minimize flow restriction to the pumping plant.

The amount and composition of the predator load in the primary channel is likely to fluctuate throughout the year depending on their relative abundances, prey availability, and salvage rates as the primary channel entrains additional fish and the downstream primary louver barriers are lifted daily for cleaning. Entrained fish are consistently added to the primary channel as water is pumped from the Delta and fish residing downstream of the TFCF can access the primary channel when the louver panels are lifted thus, creating an environment favorable to predators.

Adult and juvenile delta smelt are typically observed at low frequency (*i.e.*, 1–2 fish per 10-min count), which is equivalent to 12–24 fish per 2-h period. Conversely, juvenile salmon and juvenile steelhead can be entrained in higher numbers during their outmigration which can equate to hundreds of fish lost through the screens during a 2-h period. For every fish salvaged, six are believed to pass through the screens and not be salvaged. A small amount of predators present in the primary channel could have a severe impact on the number of native fish salvaged. Numerically, juvenile salmon are more abundant than steelhead or delta smelt but may attract more predators when they are present thus, creating a feeding environment unfavorable for passage and collection. In any case, salvage efficiency may be reduced significantly through non-native fish predation and by having a large, medium, and small predators concentrating in areas upstream, downstream, and within the facility that are all vital to the facility's salvage efficiency.

All sizes of striped bass may be able to move in and out of the primary channel during cleaning operations when the primary louver panels are lifted. Therefore, it may not be feasible to maintain a predator-free environment within the TFCF without changing primary louver panel cleaning strategies as well as to employ predator removal techniques. Without employing predator removal strategies, the predator load could possibly be held at a nearly constant rate both daily and seasonally. As part of this favorable predator environment, sub-adult and juvenile striped bass may quickly become too wide to swim upstream out through the trashrack and back into the Delta. By removing predators in the primary channel, short-term fish insertion and passage tests can be performed to examine the impact of the existing predator load.

Preliminary Results from FY 2009

Preliminary results for the predator impacts to delta smelt have been summarized in the Table 1 where approximately 100 kg of striped bass were removed during the afternoon hours of December 17, 2009. Prior to gill-netting the predators from the primary channel, whole facility efficiency ranged from 3–18% and after the gill-netting was performed, whole facility efficiency ranged from 7–48%. However, the 7% post gill-net value appears to be an outlier whereas, the remaining values range from 18–48%.

Table 1. Pre and post whole facility efficiencies for delta smelt, December 2008.

Date	Experiment #	Primary Channel Velocity (Ft/Sec)	Secondary Channel Velocity (Ft/Sec)	Whole Facility Efficiency	Primary Channel Efficiency	Secondary Channel Efficiency
12.16.08	12.15.08_#4	0.85	2.48	0.05	0.08	0.60
12.16.08	12.15.08_#5	0.82	2.59	0.03	0.05	0.80
12.16.08	12.15.08_#6	0.81	2.52	0.04	0.07	0.58
12.17.08	12.16.08_#7	0.90	2.52	0.18	0.22	0.60
12.17.08	12.16.08_#8	0.91	2.58	0.10	0.20	0.75
12.17.08	12.16.08_#9	0.88	2.46	0.16	0.26	0.80
Date	Experiment #	Primary Channel Velocity (Ft/Sec)	Secondary Channel Velocity (Ft/Sec)	Whole Facility Efficiency	Primary Channel Efficiency	Secondary Channel Efficiency
12.18.08	12.18.08_#1	0.73	2.52	0.21	0.30	0.68
12.18.08	12.18.08_#2	0.81	2.40	0.07	0.14	0.88
12.18.08	12.18.08_#3	0.81	2.40	0.18	0.20	0.65
12.19.08	12.19.08_#4	0.86	2.48	0.35	0.48	0.83
12.19.08	12.19.08_#5	0.87	2.54	0.48	0.56	0.93
12.19.08	12.19.08_#6	0.83	2.41	0.30	0.39	0.70

Preliminary results for the predator impacts to Chinook salmon have been summarized in the Table 2 where approximately 156 kilograms of striped bass were removed on April 22, 2009. Prior to gill-netting the predators from the primary channel, whole facility efficiency ranged from 0–31% and after the gill-netting was performed, whole facility efficiency ranged from 24–41%. However, the 31% pre gill-net value appears to be an outlier, whereas the remaining values range from 0–5%. We believe the 31% pre gill-netting whole efficiency value is due to prolonged predator inactivity within the primary channel where very few prey fish were being entrained prior to the experiment. Once the predators learned that prey fish were moving through the primary system, whole facility efficiencies dropped dramatically. After many of them were removed from the primary system, whole facility efficiencies increased greatly.

Table 2. Pre and post whole facility efficiencies for Chinook salmon, April 2009.

Date	Experiment #	Primary Channel Velocity (Ft/Sec)	Secondary Channel Velocity (Ft/Sec)	Whole Facility Efficiency	Primary Channel Efficiency	Secondary Channel Efficiency
04.21.09	04.21.09_#1	0.67	3.00	0.31	0.31	0.92
04.21.09	04.21.09_#2	0.58	3.09	0.05	0.06	0.60
04.21.09	04.21.09_#3	0.50	3.10	0.02	0.02	0.88
04.21.09	04.21.09_#4	0.57	2.97	0.05	0.06	0.98
04.21.09	04.21.09_#5	0.60	2.90	0.04	0.05	0.80
04.21.09	04.21.09_#6	0.55	2.92	0.00	0.00	0.80
Date	Experiment #	Primary Channel Velocity (Ft/Sec)	Secondary Channel Velocity (Ft/Sec)	Whole Facility Efficiency	Primary Channel Efficiency	Secondary Channel Efficiency
04.23.09	04.23.09_#1	0.55	3.02	0.39	0.40	0.95
04.23.09	04.23.09_#2	0.50	3.02	0.24	0.25	0.75
04.23.09	04.23.09_#3	0.65	3.04	0.41	0.42	0.68
04.23.09	04.23.09_#4	0.75	3.02	0.35	0.36	0.93
04.23.09	04.23.09_#5	0.75	2.98	0.27	0.31	0.88
04.23.09	04.23.09_#6	0.75	2.90	0.30	0.33	0.85

Problem Statement

Although it is widely recognized that non-native predator fish are consuming native fish as prey, the amount and magnitude is unknown for the TFCF. However, the impact of the predator-prey relationship may likely be severe enough to negatively distort the reported number of native threatened and endangered fish being salvaged. Therefore, the goal of this research is to determine whether the existing non-native predator population in the primary and secondary channel is significantly reducing the number of native fish reaching the holding tanks.

Goals and Hypotheses

Goal:

1. Determine whether or not the existing non-native predator population in the primary and secondary channel is significantly reducing the number of native fish (ESA species) being salvaged.

Null Hypotheses listed below will be tested:

1. There will be no difference in the percent of salvage efficiency of marked delta smelt and/or juvenile Chinook salmon after large and small predators are removed from the primary channel.
2. There will be no difference in the salvage efficiency of marked delta smelt and/or juvenile Chinook salmon released at four different locations downstream of the trashrack after large and small predators are removed from the primary channel.

Materials and Methods

Test Location and Equipment

Delta smelt or juvenile salmon will be inserted at the mid-point of the four southern bay locations behind the TFCF trashrack before (control) and after (treatment) conducting a primary channel predator removal. The experiment will be initiated (control group releases) before striped bass and other non-native predatory fish are removed from the primary channel. Fish releases for the “treatment group” will occur

after large striped bass predators are gill-netted (using 13.335-cm; 5¼-in mesh) and smaller sub-adult striped bass are also gill netted (using 7.62- to 10.16-cm; 3- to 4-in mesh) from the primary channel.

The selection to use delta smelt and/or juvenile Chinook salmon for the experiment will depend on their availability however; it may be possible to inject both species concurrently. If these species are not available, threadfin or juvenile American shad may serve as a surrogate. The number of trials will be limited to the periods when flow through the TFCF is shut down or minimized (*e.g.*, Vernalis Adaptive Management Plan Experiment, *VAMP*, which typically occurs from mid-April to mid-May) or held at a very low rate (*e.g.*, winter pumping when water demand is small). Gill netting within the primary channel is mostly feasible when there is little to no flow through the channel. However, it is still possible to gill net during higher channel flows but may require additional personnel and equipment. In addition, there must be sufficient time between trials to allow the primary channel to re-populate with predator fish.

Both control and treatment test fish will be released at the mid-point section of the four bays downstream of the trashrack (skipping the north bay where velocity is unusually slow) using 100 delta smelt/insertion (25 fish/bay with 4 unique tags) and 100 salmon/insertion (25 fish/bay also with 4 unique tags). If shad are to be used, we will use 100 fish/insertion (25 fish/bay). Control fish will be released using the same handling methods and equipment as the treatment fish but before the primary channel large and sub-adult predator removals occur. In addition, two sets of marked fish will be released in front of the sieve net (10 fish per 100 fish/primary insertion) and in the holding tank (10 per 100 fish/primary insertion) to measure sieve net and holding tank collection efficiency. Black buckets (18.93 L or 5 gal) will be used to release the test fish by lowering it into the water and gently tipping it to release the fish to best mimic a water to water transfer.

TFCF whole facility efficiency will be calculated as in Equation 1:

$$\text{EQ (1)} \quad \text{WFE} = (H * H_e^{-1}) / (I_p * H_e^{-1})$$

where,

WFE = whole facility efficiency,
 H = number of fish recovered from the holding tank,
 H_e^{-1} = counting station efficiency for determining the number of holding tank fish,
 I_p = number of fish injected into the primary channel at the trashrack.

TFCF Secondary Louver Efficiency will be calculated as in Equation 2:

$$\text{EQ (2)} \quad \text{SLE} = (H * H_e^{-1}) / ((H * H_e^{-1}) + (S * S_e^{-1}) + E_s)$$

where,

SLE = Secondary Louver Efficiency,
 H = number of fish recovered from the holding tank,

H_e^{-1} = counting station efficiency for determining the number of holding tank fish,
 S = number of fish recovered in the sieve net,
 S_e^{-1} = efficiency of sieve net for capturing fish inserted in the secondary channel behind the louvers, and
 E_s = delta smelt/Chinook salmon recovered from stomachs of predators.

Primary louver efficiency will be calculated as in Equation 3:

$$\text{EQ (3)} \quad \text{PLE} = ((H * H_e^{-1}) + (S * S_e^{-1})) / (I_p * H_e^{-1})$$

where,

PLE = primary louver efficiency,
 H = number of fish recovered from the holding tank,
 H_e^{-1} = counting station efficiency for determining the number of holding tank fish,
 S = number of fish recovered in the sieve net,
 S_e^{-1} = efficiency of sieve net for capturing fish inserted in the secondary channel behind the louvers
 I_p = number of fish injected into the primary channel at the trashrack.

Fish Source and Care

Delta smelt will be obtained from the Fish Conservation and Culture Laboratory (UC-Davis facility located in Byron, California). Juvenile Chinook salmon will be obtained from a local hatchery and held at the Tracy Aquaculture Facility (TAF). Shad can be collected in the TFCF and held in the TAF. Fish will be marked using fluorescent pigments (BMX biobead, New West Technology) approximately 3 weeks prior to insertions. Each replicate will be assigned a unique tag to differentiate between fish released at different locations (four locations) and times (six insertions). Fish will be held in outdoor tanks (4 ft diameter) at the TAF under ambient water and weather conditions. Test fish will be acclimated (<1.0 °C/day) to spring-time Delta water temperatures (~16 °C) and quality 1 week prior to insertion.

Predation experiment

Test fish (control group) will be inserted behind the trashrack (four locations at mid-point of each bay, except for bay 5 where velocity is unusually slow) at 30-min intervals. Sieve nets and holding tanks will be switched (sampled) every 30 min to determine collection efficiency and fish passage rate. All wild fish will be sorted, counted, and released into the fish haul-out tanks as quickly as possible. The location and time of all marked fish that are re-captured will be recorded and the fish will be held temporarily for reference. The primary louvers will not be lifted during the experiment and gill nets will be used in the primary channel to collect as many predators as possible. The initial salvage rate experiment will release then collect control test fish then use 13.335-cm (5¼-in) mesh size gill nets to remove large predators. During the following day we will perform the same experiment but will use smaller 7.62- to 10.16-cm (or 3- to

4-in) mesh size gill nets to remove a large portion of the smaller sub-adult striped bass from the primary channel. Sub-adult striped bass (age 2+, 26–47 cm fork length) are primarily piscivorous and along with adult striped bass, often concentrate near screening diversions feeding on small fish, especially juvenile salmon. Both size classes of striped bass are a major source of mortality of juvenile salmon and other fishes entrained by the south delta water project pumps (Moyle 2002).

The goal of this activity is to remove adult and sub-adult (striped bass) predators to increase salvage efficiency and also to disturb the remaining predators during the gill-netting so that they are less likely to feed during the subsequent insertions. For fiscal year 2010, we are planning on obtaining one to two replicates during the winter low flow period and one to two replicates during VAMP. The difference in salvage efficiency between the control test fish and the treatment test fish will estimate the impact of predation between a common predatorily influenced primary channel and a predatorily depleted primary channel. Whole facility efficiency data collected for each pre and post predator removal will count as one replicate. The difference in salvage efficiency between the control and treatment conditions may be a conservative estimate of the impact of the predators in the primary channel as it will be unlikely that all of the predators will be removed or disturbed enough to curtail feeding activity. In addition, the time period during VAMP may not be long enough to accurately represent a re-populated predatorily influence primary channel; however, if VAMP is prolonged predators may re-populate the primary system.

Data Analysis/Interpretation

A paired, two-tailed t-test will be used to compare mean collection efficiencies of the control versus treatment groups. An alpha level of 0.05 will be used to detect statistical significance. If there is a significant difference found, then a one-way-ANOVA will be used to compare the percent collection loss by release point. Predator abundance data will also be used to estimate seasonal consumption of delta smelt and Chinook salmon using Fish Bioenergetics 3.0 (Hanson *et al.* 1997). The model will estimate minimum, maximum, and average daily feeding rates striped bass.

Coordination and Collaboration

This research will be coordinated and conducted by the TFCF fisheries staff and the Fish and Wildlife Resources Group (TSC 86-68290) and interested interagency TTAT groups.

Endangered Species Concerns

The incidental capture of any juvenile steelhead, juvenile Chinook salmon or delta smelt will be returned to Delta waters as quickly as possible. The total number of each ESA species incidentally caught or collected during the experiment will be recorded and sent to the reporting agencies. However, gill net mesh size should allow juvenile Chinook salmon, steelhead and delta smelt to pass through safely.

Dissemination of Results (Deliverables and Outcomes)

Field work will be done in FY 2009 and FY 2010, and possibly FY 2011. Data analysis and a draft Tracy Series Report will be completed the following fiscal year after the field work has been completed (FY 2011 or FY 2012).

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